15. Material flows in the circular economy

Key points:

- Construction minerals, which are stocked in assets with long lifetimes (e.g. buildings and infrastructure), make up a large part of the EU's material use by mass.
- Recycling and backfilling[144] accounted for about 8 % of overall material inputs to the EU economy in 2014. The contribution of recycling varies by material category and is highest for metals.
- Even with increasing end-of-life re-use and recycling rates, primary resource extraction would still be needed to meet the EU's materials demand.

Overview and context

Using the analogy of biological systems, Frosch and Gallopoulos[145] envisioned an economy in which flows of energy and materials are optimised, waste generation is reduced, and by-products are used beneficially in co-located processes. Since 2015, the European Commission has launched two circular economy packages to encourage and steer Europe's transition towards a more circular economy[146]. Circular economy is defined as a state in which 'the value of products, materials, and resources is maintained in the economy for as long as possible, and the generation of waste is minimised[147]'. In this context it is essential to understand an economy's societal metabolism[148], i.e. to quantify the amount of materials flowing in and out of the economy, and monitor how they are used in society and their level of circularity. The Commission's 2018 circular economy package therefore includes items like a monitoring framework to measure progress towards a circular economy at both EU and national level[149]. This monitoring framework consists of material flow visualisations and a set of 10 key indicators which cover each phase of a raw material's life cycle and the related economic aspects.

We can easily relate the present visualisation of material flows to other indicators of this Scoreboard's circular economy cluster. For example: (i) flows of materials can be combined to calculate end-of-life recycling input rates (Indicator 16); (ii) flows of waste and scrap are widely traded both within and outside the EU (Indicator 17); (iii) flows of waste electrical and electronic equipment (WEEE) are a small but relevant flow (as they contain large quantities of precious metals) and leave the societal stocks as waste (Indicator 18); and (iv) construction and demolition waste are the biggest flow of waste in the EU (Indicator 19).

Facts and figures

Figure 15.1 shows material flows through the EU-28 economy in 2014, in line with the European Commission's monitoring framework[150]. This figure expands upon the 2016 Raw Material Scoreboard as it combines Eurostat data on material flows (inputs) and waste (outputs)[151] with additional modelling efforts[152]. The figure includes food and feed in the energetic use of biomass.

Figure 15.1 shows that in 2014 more than 72 % (5.8 Gt) of the mass of raw materials used in the EU originated from domestic extraction, 19 % (1.5 Gt) from imports and 8 % (0.7 Gt) from recycling (see also recycling-related Indicator 16) and backfilling (0.06 Gt). More information can be found in Indicator 3 on import reliance.

Of the 8 Gt of materials that are processed in the EU economy, 39 % (3.1 Gt) are used for energy, 53 % (4.3 Gt) are used as materials, and 8 % (0.6 Gt) are exported.

Short-lived products with a lifespan of less than one year, along with manufacturing losses, account for 0.8 Gt of all material use. The remaining 86 % (3.5 Gt), which mostly consist of construction minerals, are used to build up and maintain societal in-use stocks (e.g. buildings, infrastructure and other goods with long lifespans). These stocks will only become available for recycling once the

144 "Backfilling" means any recovery operation where suitable non-hazardous waste is used for purposes of reclamation in excavated areas or for engineering purposes in landscaping. Waste used for backfilling must substitute non-waste materials, be suitable for the aforementioned purposes, and be limited to the amount strictly necessary to achieve those purposes' (Directive of the European Parliament and of the Council amending Directive 2008/98/EC on Waste, PE 11 2018 REV 2, 30.05.02017).

145 Frosch, R. and N.E. Gallopoulos, 1989, 'Strategies for Manufacturing', Scientific American 3(261): 144-152.

146 http://ec.europa.eu/environment/circular-economy/index_en.htm.

147 COM(2015) 614 final. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. 'Closing the loop — An EU action plan for the Circular Economy'.

148 The term 'metabolism', applied to natural systems, includes the transformations of inputs (sunlight, chemical energy, water, air, nutrients) needed by an organism to properly function, and related waste products. 'Societal metabolism', by analogy, refers to the flows of materials, energy, and waste in the economic system.

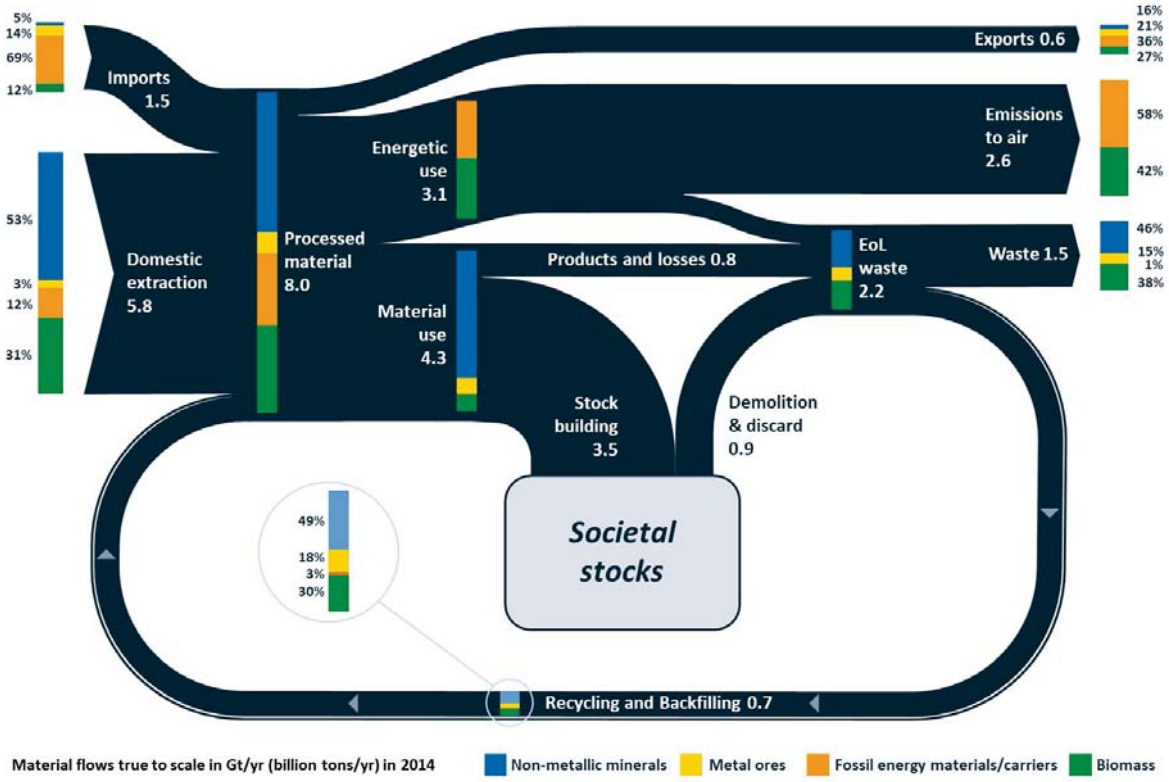
149 COM(2018)29 final."Monitoring Framework for the Circular Economy'.

150 COM(2018)29 final."Monitoring Framework for the Circular Economy'.

151 Nuss P., Blengini G.A., Haas W., Mayer A., Nita V, Pennington D., 2017, 'Development of a Sankey Diagram of Material Flows in the EU Economy based on Eurostat Data', EUR 28811 EN, Publications Office of the European Union, Luxembourg, doi.2760/362116.

152 Mayer A., Haas W., Wiedenhofer D., Krausmann F., Nuss P., Blengini G.A., 'Measuring progress towards a Circular Economy - a monitoring framework for economy-wide material loop closing in the EU28". Accepted for publication by Journal of Industrial Ecology. doi: 10.1111/jiec.12809.

Figure 15.1: Material flows in the economy (EU-28, 2014)[153].



long-life goods reach their end-of-life. Demolition & discards flows account for 0.9 Gt.

Together with waste from other material and energy use, the total end-of-life waste generated equals 2.2 Gt, of which 0.6 Gt remain in the EU economy through recycling and 0.06 Gt through backfilling (approximately 0.7 Gt in total). This recycling stream equals 30 % of all material waste flows. On the other hand, 4.1 Gt of materials leave the economy e.g. as emissions to air and waste disposal.

Based on the material flows visualisation described above, Figure 15.2 provides additional insights into the flow of individual material categories in the EU-28.

Non-metallic minerals (top left), including construction minerals and industrial minerals, represent nearly half of the EU-28's mass material use (3.1 Gt) (see also Indicator 19 for recycling rates of construction and demolition waste). Around 3.1 Gt were added to societal in-use stocks and around 0.7 Gt were discarded, resulting in an overall growth of societal in-use stocks in the EU. About 0.35 Gt of all non-metallic minerals were recovered (0.3 Gt recycling and 0.05 Gt backfilling), equivalent to 10 % of all inputs.

Despite their high economic and strategic importance, metal ores (top right) only represent a minor proportion of the EU-28's material consumption in terms of mass. A large share of metals (59 % or 0.22 Gt) come from imports. Of the 0.35 Gt of metals processed in 2014 (excluding extractive waste), 34 % (0.12 Gt) originated from domestic recycling in the EU. More than half of the processed metals were integrated into societal in-use stocks. The domestic extraction of metals (gross ores) splits into pure metal and extractive waste flows (0.17 Gt) which become end-of-life waste.

Nearly a fifth of processed biomass (bottom left), most of which is wood from domestic extraction, is used for material uses. About 9 % (0.2 Gt) of processed biomass is secondary biomass from recycling. Approximately 18 % (0.4 Gt) of processed biomass is used for material purposes such as pulp and paper production, for construction purposes, or for manufacturing other wood products (e.g. furniture). About 9 % (0.2 Gt) of processed biomass is added to societal in-use stocks.

Most fossil fuels (bottom right) are used for their energetic value. Less than 3 % of processed fossil energy carriers are used as plastic, oils, tyres, or for chemical purposes — where carbon could be recovered at end-of-life. In fact, 54 % of these materials were recovered.

In other words, the circular use of raw materials in the EU is limited by the energetic use of biomass (1.1 Gt, for purposes such as food, feed and agro fuels) and of fossil resources (1.45 Gt).

153 Source: Mayer A., Haas W., Wiedenhofer D., Krausmann F., Nuss P., Blengini G.A., 'Measuring progress towards a Circular Economy - a monitoring framework for economy-wide material loop closing in the EU28". Accepted for publication by Journal of Industrial Ecology. doi: 10.1111/jiec.12809.

Figure 15.2: Material flows for single material categories in the EU-28 economy (in Gt/yr (billion tons/year) in 2014[154].

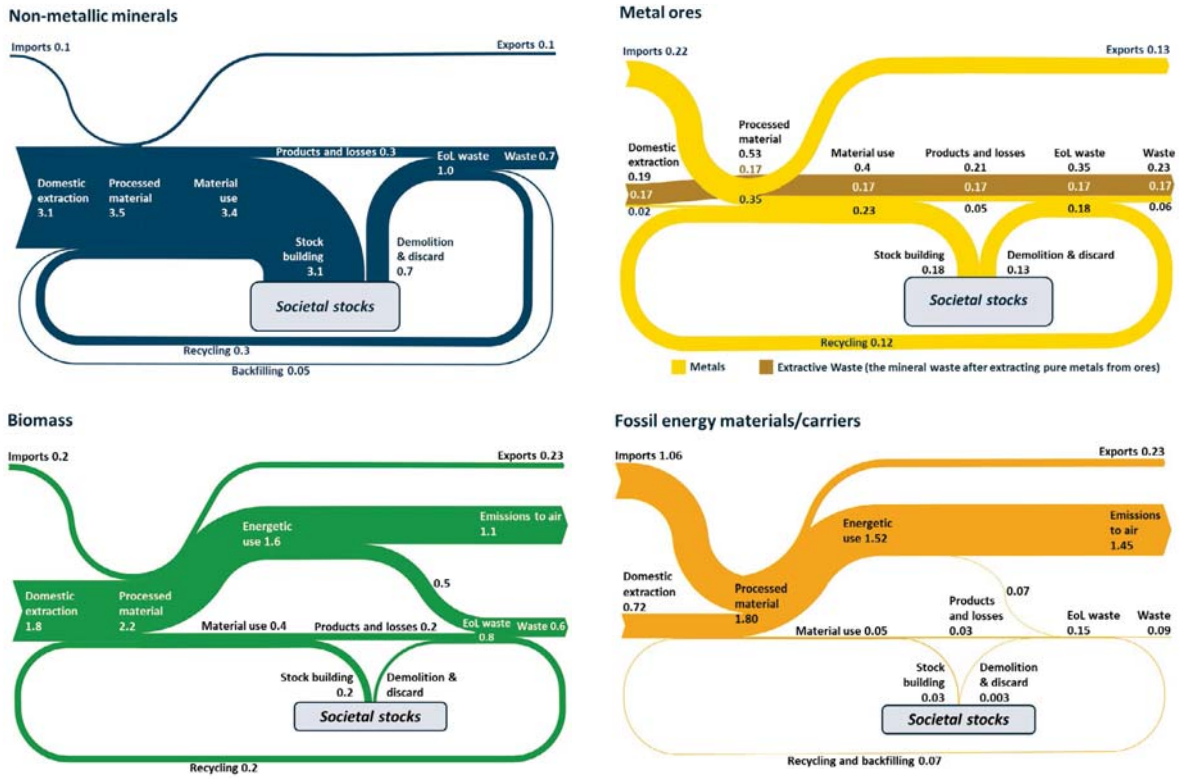


Figure 15.3 provides further details on the EU-28's use of materials by presenting data on domestic material consumption (DMC) between 2002 and 2016 (2015 for individual materials). It shows that overall DMC decreased by 13 % between 2000 and 2016 (Figure 15.3A) and that it fell sharply (-20 %) between 2007 and 2016. Over the whole period, the decreasing consumption of construction materials — construction being a sector strongly affected by the economic crisis — was the primary cause for the fall in domestic material consumption.

The breakdown by material set out below shows that sand and gravel, together with limestone and gypsum, make up the bulk of non-metallic minerals (Figure 15.3B). In the case of metals (Figure 15.3C), iron and copper are the most widely used in the EU. The trend in the various metals shows that iron consumption was also affected by the economic crisis, even though it recovered quickly after 2010, due to demand for steel in construction and transportation equipment. On the other hand, the growing consumption of copper, gold, silver, platinum and other precious metals may be explained by the increasing demand for low-carbon energy technologies and high-tech applications. Finally, biotic materials (of which roundwood only represents a relatively small part) is the only materials category that has remained relatively constant over this 13-year period (Figure 15.3D).

Conclusion

In January 2018 the European Commission adopted a new set of measures[155] as part of its ongoing support to the transition to a more circular economy. These include: (i) a strategy towards a more circular use of plastics; (ii) options to address the interface between chemical products and waste legislation; (iii) information on circular use of critical raw materials; and (iv) a monitoring framework towards a circular economy.

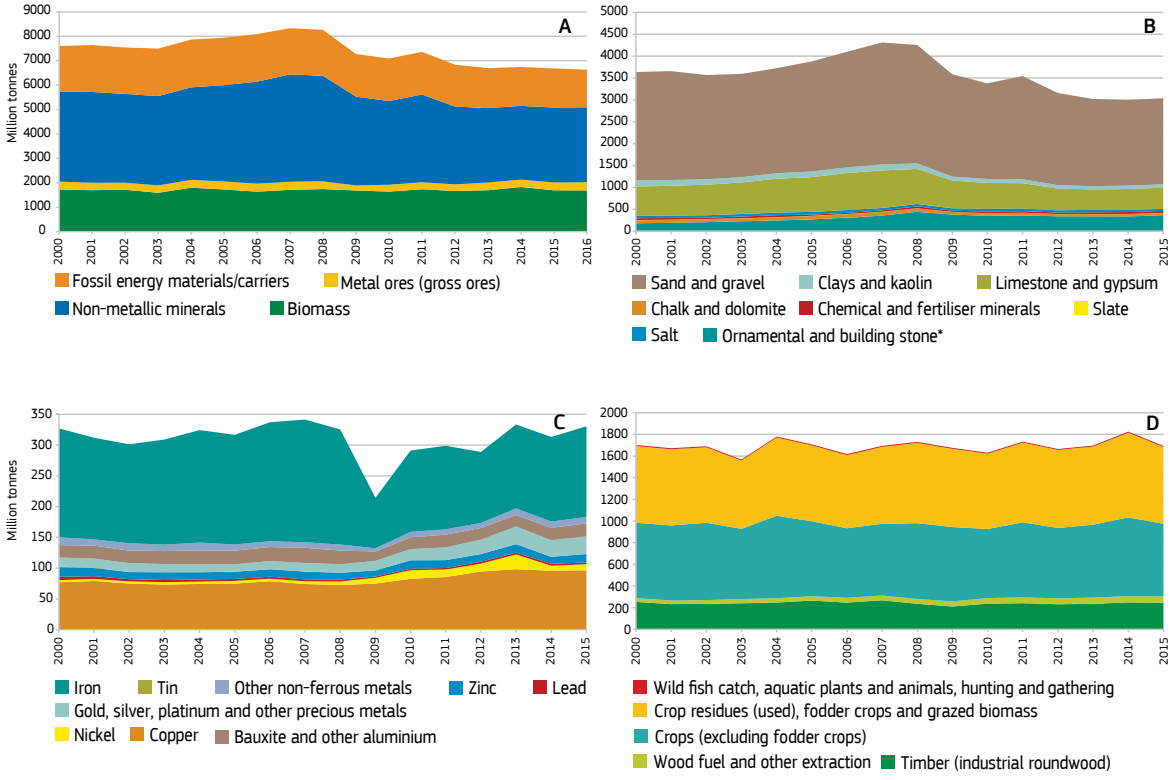
Material flow visualisations show that a large part of the EU's mass material use consists of construction materials, many of which are accumulated in long-living in-use stocks. In-use stocks for products made from metals, biomass, and fossil fuels are also growing. The level of circularity varies by material and is the highest for metals.

The economy's circularity could be improved by increasing the re-use and recycling rates of materials (production processes and products), whenever is technically and economically feasible, as well as by increasing the durability, reparability, upgradability of products that remain in in-use stocks. Even with increasing end-of-life re-use and recycling rates, primary resource extraction would still be needed to meet the EU's materials demand. This is because it will take at least decades for materials contained in some growing in-use stocks to become available for recycling. Therefore, sustainable materials extraction and efficient use of resources will continue to be of paramount importance.

154 Source: Mayer A., Haas W., Wiedenhofer D., Krausmann F., Nuss P., Blengini G.A., 'Measuring progress towards a Circular Economy - a monitoring framework for economy-wide material loop closing in the EU28". Accepted for publication by Journal of Industrial Ecology. doi: 10.1111/jiec.12809.

155 http://ec.europa.eu/environment/circular-economy/index_en.htm.

Figure 15.3: Domestic material consumption by resource category (EU-28, 2002-2016)[156]. (A: main raw materials groups; B: non-metallic minerals; C: metals; and D: biomass).



The search for suitable data…

Given the need to combine different data sources in material flow analysis, Sankey diagrams of EU material flows inevitably have certain limitations. The authors of the Sankey diagram acknowledge that in Figures 15.1 and 15.2 there are possible inaccuracies (up to ± 30 %) and that data are sometimes lacking[157]. Nonetheless, they deem the data reliability as sufficient to provide an approximate but comprehensive assessment of the circularity of an economy at the level of material groups.

The European Commission has published complementary studies on material system analysis for individual materials[158,159], as well as material flow visualisations of Eurostat data for individual EU Member States[160], and continues to work on harmonising and improving the quality of material flow data and data on waste management.

The MinFuture[161] project funded by the Horizon 2020 Framework Programme of the European Union enhances collaboration among key institutions that provide or use global resource data. The project also develops and tests a common methodology to measure global cycles of materials.

156 Source: JRC elaboration, based on Eurostat Economy-wide material flow accounts (see also methodological notes).
157 See Annex 2 of SWD(2018) 17 final. Commission Staff Working Document. 'Measuring progress toward circular economy in the European Union — Key indicators for a monitoring framework'.
158 Bio by Deloitte, 2015, 'Study on Data for a Raw Material System Analysis: Roadmap and Test of the Fully Operational MSA for Raw Materials', prepared for the European Commission, DG GROW.
159 Passarini F., Ciacci L., Nuss P., Manfredi S., 2018, 'Material Flow Analysis of Aluminium, Copper, and iron in the EU-28', EUR 29220 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-85744-7, doi.10.2760/1079, JRC111643 http://europa.eu/!mh49cu.
160 Nuss P., Blengini G.A., Haas W., Mayer A., Nita V, Pennington D., 2017, 'Development of a Sankey Diagram of Material Flows in the EU Economy based on Eurostat Data', EUR 28811 EN, Publications Office of the European Union, Luxembourg, doi.2760/362116.
161 https://minfuture.eu/

Methodological notes

Figure 15.1 and 15.2

The Sankey diagram uses the available Eurostat data from the EW-MFA for raw materials inputs from domestic extraction and imports and to capture exports to non-EU countries. The allocation of material flows into the different material categories and the split between energetic and material use are based on a recent scientific publication. Conversion factors to calculate the amount of metal vs extractive waste are based on Eurostat data ('Economy-wide material flow accounts (EW-MFA) Compilation Guide 2013').

Eurostat waste treatment statistics are used and, where necessary, are complemented to model the amounts of waste at end-of-life, recycling and backfilling flows and waste crossing into nature. Because the waste flows are reported using different classifications than the EW-MFA, they were reallocated to match the material flow accounts (material categories) using a mix of information, e.g. from the scientific literature and expert opinions.

Detailed methodological details of the Sankey diagram are given in Annex 2 of SWD(2018) 17 final, Commission Staff Working Document 'Measuring progress toward circular economy in the European Union — Key indicators for a monitoring framework'.

Figure 15.3

Indicator definition

Domestic Material Consumption (DMC) is one of the indicators that can be derived from economy-wide material flow accounts (EW-MFA). For the aggregated EU economy DMC = domestic extraction + extra-EU imports - extra-EU exports.

DMC includes the following components, each with different underlying measurement concepts: (i) domestic extraction (DE); and (ii) trade (imports and exports). Domestic extraction is measured in tonnes of gross ore (or gross harvest) whereas imports and exports are measured as the mass weight of products as they cross country borders. However, the weight of a traded product is not equivalent to the domestic extraction of materials necessary to produce the traded product. The figures presented in Figure 15.3 might slightly differ from those shown in Figures 15.1 and 15.2 due to the combination of Eurostat statistics with other circular economy data sources and Sankey visualisations.

Material categories

A. Main raw materials groups	
MF1	Biomass
MF2	Metal ores (gross ores)
MF3	Non-metallic minerals
MF4	Fossil energy materials/carriers
B. Non-metallic minerals	
MF31	Marble, granite, sandstone, porphyry, basalt, other ornamental or building stone (excluding slate)[1]
MF32	Chalk and dolomite
MF33	Slate
MF34	Chemical and fertiliser minerals
MF35	Salt
MF36	Limestone and gypsum
MF37	Clays and kaolin
MF38	Sand and gravel
MF39	Other non-metallic minerals n.e.c.[2]
C. Metals*	
MF21	Iron
MF221	Copper
MF222	Nickel
MF223	Lead
MF224	Zinc
MF225	Tin
MF226	Gold, silver, platinum and other precious metals
MF227	Bauxite and other aluminium
MF229	Other non-ferrous metals
D. Biomass[3]	
MF11	Crops (excluding fodder crops)
MF12	Crop residues (used), fodder crops and grazed biomass
MF131	Timber (industrial roundwood)
MF132	Wood fuel and other extraction
MF14	Wild fish catch, aquatic plants and animals, hunting and gathering

*Uranium and thorium (MF228) were left out as the scope is limited to non-energy and non-fuel raw materials.